INSPECTION OF HABITABLE MODULE OR PRESSURE VESSEL WELDS AFTER PROOF TESTING

Technical necessity and value for post-proof inspection of welds involves a number of considerations and requires a clear understanding of fracture control requirements, structural verification requirements, the relationship between habitable modules and pressure vessels (because of existing confusion), and safety philosophy.

For fracture control, "pressure vessels" and "habitable modules" are defined and addressed individually in SSP 30558C, "Fracture Control Requirements for Space Station". This is because habitable modules do not fit the pressure vessel definition and must be covered by a separate classification. This classification was developed for SSP 30558C to clearly differentiate pressure vessels and habitable modules. It might be noted that if pressure vessel requirements were directly and strictly applied to a habitable module the cost of a flight module would be greatly increased. As an example, a separate structural qualification test module, that would be eventually destroyed, would be required. This is not technically necessary when other defined tests and controls, specifically developed to assure structural integrity and safety of a habitable module, are applied .

However, it is not classification as a pressure vessel or a habitable module that makes a difference in whether welds must be inspected after proof testing. It is a matter of safety philosophy for pressurized hardware and avoidance of costs that do not tangibly increase safety. The philosophy and methodology are based on fracture control and address safety only (safety is the purpose of NASA fracture control requirements). Fracture control is not *required* for assurance of reliability or performance.

A pressure vessel or a module with a "leak-before-burst" design (using fracture control methodology) can eventually develop slow leakage if a large enough flaw is present and enough loading cycles are applied during service. If the fluid that would be leaked is not hazardous in itself and slow loss of the fluid is not hazardous for the application then such a failure would be benign in the context of safety. If the design is not leak-before-burst (fragmentary or abrupt rupture is possible) or leakage of fluid is a hazard then failure would be hazardous and "safe-life" assurance through fracture control methodology is required for full assurance of safety. These basic tenets underlie whether inspection of welds after proof testing is required for safety.

If "safe-life" is required, the initial (starting) flaw size in the flight hardware must be bounded to the extent necessary to assure rupture or leakage will not occur. Proof testing can "open up" or can grow existing flaws, or, in some cases, generate cracking. Inspection after proof testing is mandatory for "safe-life" hardware because existing flaws, not previously in evidence with pre-proof inspection may have developed, or grown to unacceptable size, or detection may have been enhanced by the proof strain. If the hardware is leak-before-burst and leakage is non-hazardous then the presence of flaws after proof testing is important for reliability (actual life), but is not significant information for safety.

It should always be remembered that fracture control is a safety requirement for avoidance of catastrophic hazards/events. It is unfortunate that decisions made for safety, based on fracture control, are defaulted into other areas.

A decision or position that a post-proof inspection of a weld is not necessary for safety is not a decision or position that a post proof inspection of the same weld is not necessary to full assurance of service life. For "*safe-life*" designs a post-proof inspection of welds is *always* necessary, from a fracture control aspect, to assure service life, hence assure safety. Ideally, all primary structure welds that are proof tested should be inspected after proof testing. This is especially true if weld failure would cause loss of the use of a major space asset, even though no safety hazard or destruction of the asset is associated with the failure. Most fracture control programs will have this requirement.

The philosophy regarding failure mode, based on fracture control methodology and required inspections for safety, has provided the payload community with significant latitude to reduce costs and use more "off-the-shelf" pressure vessel designs without any sacrifice of safety and essentially little, if any, affect on reliability. The same philosophy is applicable to the safety of habitable modules. However, there is more to structural integrity and structural verification than just fracture control requirements for safety. This fact seems to be frequently lost in hardware assessments and discussions of hardware acceptability.

It is incumbent on project managers and designers to assure system and component integrity and reliability. Fracture control methodology can be applied to achieve this, but is not a NASA requirement for this purpose. It is the responsibility of the Project to provide assurance that requirements that are necessary to achieve reliability, including fracture control methodolgy if such methodology is significant to life or performance, are applied to the given hardware. Structural verification should reflect this. The responsible safety authority has no direct responsibility in these areas. Decisions based on safety considerations, such as acceptance of the absence of post-proof inspection of the MPLM welds, may not always accommodate life or performance issues or concerns, and may involve special considerations not existing for other applications. Such decisions should not be regarded as modification or mitigation of any existing requirements.

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